TRITON ENVIRONMENTAL, INC.
Environmental Consulting & Engineering

April 12, 2017

Ms. Susan Studlien
Director
Office of Environmental Stewardship
U.S. Environmental Protection Agency
5 Post Office Square, Suite100
Boston Massachusetts 02109-3912

Attn: Elizabeth Kudarauskas (OES 04-2)

RE: Clean Air Act Reporting Requirement and Testing Order Response Letter
Hudson Terminal Corporation – Providence, RI

Dear Ms. Studlien:

Triton Environmental, Inc. (Triton) is writing on behalf of Hudson Terminal Corporation (Hudson) in response to the United States Environmental Protection Agency's (EPA) letter dated January 3, 2017. Below in italic text are requests made by the EPA to Hudson with Hudson's responses in regular text.

1. *Provide the following information about the facility:*
   a. *Describe the ownership and business structure;*
   b. *Indicate the date and state of incorporation;*
   c. *List any partners or corporate officers;*
   d. *List any parent and subsidiary corporations;*
   e. *Provide the net worth of the owner.*

   a. The company is established as an S-Corp with two stockholders.
   b. The company was incorporated on June 22, 1962 in the state of Rhode Island.
   c. Thomas F. Hudson (stockholder) - President
      John J. Hudson (stockholder) – Senior Vice President, Secretary
      Thomas J. Hudson (Vice President)
   d. NA
   e. NA

385 Church Street, Suite 201, Guilford, CT 06437
Phone: 203.458.7200 Fax: 203.458.7201

2. *Provide the actual annual throughput of asphalt by providing the amount of asphalt product received and the amount of asphalt product shipped offsite for the facility from 2011 to present (in gallons).*

    a. *For asphalt product received, include the product type, quantity and the date of receipt.*

    See the attached tables (Table 1 – Asphalt Shipped (2011-2016) and Tables 2-7 – Asphalt Received (2011-2016) for the requested information regarding shipment and receipt of asphalt.

3. *Calculate the maximum daily, monthly and annual design throughput capacity of asphalt for the Hudson Terminal facility. When providing the maximum capacity consider facility-specific factors such as number and storage capacity of storage tanks, tank fill rate limitations, loading rack restrictions, and heat, system limitations. Provide a detailed description of how the maximum throughput capacity was calculated for the facility.*

    Throughput operations at Hudson Terminal generally consist of the transfer of asphalt from ships/barges at the terminal dock to bulk storage tanks in the tank farm, the transfer of asphalt from the bulk storage tanks to "day tanks", and loading trucks in the yard. Hudson has reviewed their equipment, operations, and related restrictions to calculate the potential throughput capacity of each of these segments as presented below. Based on this review, Hudson has determined the maximum throughput capacity to be based on truck loading as follows:

    - Maximum Daily Throughput Capacity – 2,246,400 gallons
    - Maximum Monthly Throughput Capacity – 69,638,400 gallons
    - Maximum Annual (365 day) Throughput Capacity – 819,936,000 gallons

    It should be noted that the throughput capacities presented represent calculations assuming unlimited marketing demand for 24 hours per day, 365 days per year (8,760 hours per year). The terminal was not truly "designed" for such an unlimited demand scenario and has never experienced such conditions. This is demonstrated by Table 1 which presents annual Asphalt Shipped per year between 2011 and 2016 ranging between approximately 22,000,000 - 38,000,000 gallons per year. This actual range is well below the calculated throughput capacity of 819,936,000 gallons per year.

    <u>Dock Transfer to Bulk Tanks</u>

    Ships and barges are received at the terminal dock. Transfer operations for product delivered at the dock to bulk tanks are limited by the maximum pump rate (2,800 gallons per minute (gpm)) through an 8" flexible cargo hose. As such, the maximum daily throughput capacity at the dock was determined to be 4,032,000 gallons. Please note that this throughput capacity has not accounted for a likely reduction in the flow rate because of friction losses, pipe appurtenances (such as flanges and valves), etc. This has not been included in our review as a conservative measure and due to the complexity of attempting to quantify this restriction. Regardless, this would not be the restricting segment of Hudson's operations as day tank truck loading has a lower daily throughput capacity.

Bulk Tanks to Day Tanks

Asphalt is pumped from the bulk tanks in the tank farm to four smaller "day tanks" (Tanks A6, A7, A8, and A9) for loading into trucks in the yard. Once in the day tanks, product delivery into trucks from the tanks is controlled by valves (gravity flow) as further detailed below. Transfer operations from the bulk tanks to the day tanks is completed using two pumps with a maximum pump rate of 1,048 gpm. With both pumps operating continuously at this rate (combined flow - 2,096 gpm), the maximum daily throughput capacity was determined to be 3,018,240 gallons. Please note that this throughput capacity has not accounted for additional time likely required for the heating system to elevate the asphalt to a sellable temperature in the day tanks (375 °F) from the bulk tanks (250 °F). Neither this nor the flow rate reduction as described above for transfers to bulk tanks has been included in our review as a conservative measure and due to the complexity of attempting to quantify these restrictions. Regardless, this would not be the restricting segment of Hudson's operations as day tank truck loading has a lower daily throughput capacity.

Truck Loading

Product loading into trucks in the yard occurs at nine loading positions including seven positions at the day tanks and two at manifold/direct connections to bulk tanks. The flow rate at each of the loading positions is 800 gpm. However, the number of loading positions and flow rate of product are not the restricting variables in maximum throughput. Hudson has calculated that processing each truck at the terminal (fill rate, paperwork processing, weighing in/out at scale, truck yard navigation, etc.) results in the restriction of the maximum throughput. Specifically, the time required to process a truck is approximately 20 minutes and only one truck can enter and exit the yard every 5 minutes. Calculations completed to cycle trucks through the terminal based on these restrictions allows for a maximum of 288 trucks to be processed each day. At 7,800 gallons per truck with 288 trucks per day, the maximum throughput is 2,246,400 gallons per day.

4. *Provide a list of projected asphalt receipt shipments for 2017. Include the projected dates of receipt as well as the quantity of asphalt expected.*

   See the attached Table 8 for the project receipt shipments of asphalt at the Hudson Terminal.

5. *Describe each tank that stores asphalt at the facility. Specifically include:*
   a. *Tank size information including storage capacity, height and diameter;*
   b. *Date that each tank became operational;*
   c. *Tank type (e.g. vertical fixed roof);*
   d. *Whether the tank is insulated and if so, specific surfaces insulated (e.g. sides, roof);*
   e. *A description of any heating system for the tank including heat input capacity for each tank (in mmBtu/hr per tank);*
   f. *The storage temperature of the asphalt in the tank;*
   g. *Any controls used to reduce tank emissions. Include the removal efficiency of the controls and the date any media in the controls was last replaced;*

h. Types of vents on the tank including the vent pressure settings; and

i. The date vents and vent pressure settings were last tested.

a. See the attached Table 9 for the requested information.
b. See the attached Table 9 for the requested information.
c. See the attached Table 9 for the requested information.
d. See the attached Table 9 for the requested information.
e. The facility operates with three therm fluid heater (1) North American 23 MMBTU and (2) Heatec 10 MMBTU Natural Gas fired. The heat input capacity for each tank is provided in the attached Table 9. In calculating these values, Hudson has used the following assumptions:

    - Regional (Rhode Island (RI)) average High Temperature: 60.5 F
    - Regional (RI) average Low Temperature: 42.5 F
    - Regional (RI) average Temperature: 51.5 F
    - Regional (RI) average wind Speed: 6.5 meters per second.

f. See the attached Table 9 for the requested information.
g. There are no controls for tank emissions at the Hudson Terminal.
h. Tanks at Hudson Terminal are equipped with atmospheric vents. The tanks are not equipped with pressure relief valves or vents.
i. The tank vents at Hudson Terminal are not tested.

6. *For all equipment at the facility involved in the storage and distribution of asphalt:*

    a. Provide a list of each capital project, including but not limited to installations, repairs, and retrofits of process equipment (e.g. tank, pumps, piping) and process support equipment (e.g. heating systems) which:

    i. Had actual or authorized expenditures of $100,000 or more; and

    ii. Had commenced construction since January 1990.

    b. For each project, provide the following information:

    i. Project description;

    ii. The purpose/function of the equipment;

    iii. The cost and date of purchase;

    iv. The date installation was completed;

    v. The date the equipment began operating;

    vi. The name of the manufacturer, model number, size, maximum production rate, and any other operational specifications; and

    vii. Information pertaining to any emission control devices associated with such process equipment, including the type of emission control device, when such device was installed, and any data pertaining to emission reductions from use of *such device.*

c. *The list should include, but not be limited to the following types of capital projects:*

  i. *Conversion of a storage tank to store asphalt;*
  ii. *Insulation of storage tanks and associated piping;*
  iii. *Installation or replacement of large sections of piping;*
  iv. *Installation or replacement of a heating system that is used to maintain temperature of asphalt; and*
  v. *Installation of any type of vapor collection and control system that is used to control odors and/or reduce emissions from the storage and distribution of asphalt.*

Below is a list of facility projects meeting the criteria listed above. Please note that the facility has undergone other improvements that have not been listed since projects costs were less than the $100,000.00 threshold. For example, numerous tank roofs have been insulated, but costs did not exceed $100,000.00 on a tank by tank basis.

1. ***<u>Heatec Furnaces 10mmBTU</u>***
   i. Replacement of a 20 MM/BTU furnace with two Heatec 10 MM/BTU furnaces.
   ii. The new furnaces are high efficiency units designed to burn natural gas. Emissions from the units are substantially lower than the previous furnace that had operated primarily on No. 6 fuel oil. The furnaces provide thermal heat to maintain asphalt products at an elevated temperature throughout the terminal.
   iii. $792,000.00 / purchased 2005
   iv. Installation was complete in 2005
   v. The furnaces were operational in 2005
   vi. Two Heatec model HC1-10010-40-(D)-CGOH-R, 10 MM/BTU furnaces.
   vii. The furnaces are equipped with Fire Eye emission monitors for use while operating on No. 6 fuel oil. However, Hudson no longer burns No. 6 fuel oil in the furnaces.

2. ***<u>Hudson Terminal Tank Storage Expansion</u>***
   i. Construction of 3 asphalt storage tanks
   ii. The tanks were needed to expand the facility storage capabilities and become more competitive in the current market. Each tank has an approximately 2.27 million gallon shell capacity.
   iii. The project included asphalt tanks, insulation, heating coils pumps, foundation, and containment liner. The costs were $4,965,935.00. The tank and equipment were installed between 2006 - 2008.
   iv. Installation was complete in 2008.
   v. The tanks were operational in 2008.
   vi. Manufacturer and models:
      - Tanks: Consolidate LLC
      - Insulation: Fiber Chem Inc.
      - Heating coils: Heatec Inc.

- Asphalt Pumps: Shamosh Equipment Corp. Leistritz pumps.

vii. There are no emission control devices associated with these tanks. The tanks are equipped with atmospheric vents.

3. ***Tank 4 Project***
   i. Repairs to storage tank including insulation (bottom 14' only), new floor, vent, and manway.
   ii. The tank is needed to expand the facility storage capabilities.
   iii. Project is in progress and is estimated to cost $900,000.00 at completion.
   iv. Anticipated completion in 2017
   v. Anticipated operational in 2017
   vi. Manufacturers are Easter Piping and Phoenix Welding.
   vii. There are no emission control devices associated with the tank. The tank will be equipped with a single atmospheric vent.

Testing Order

This Testing Order requires Hudson Terminal to monitor and sample the headspace of a tank containing asphalt for volatile organic compounds ("VOC") and hazardous air pollutant ("HAP") content at the Terminal Road location.

Hudson Terminal must submit an emission test protocol, conduct emissions testing, and submit a test report in accordance with the schedule specified in the January 3, 2017 letter.

Hudson has developed the attached protocol to complete testing of a representative tank and truck loading operations as required by the subject Testing Order. Hudson has selected Tank 3 as a representative bulk tank based on numerous variables including the product type that will be handled in the tank during the test, overall size of the tank, and its vent configuration. Tank 3 is a representative size tank (approximately 1,000,000 gallons) in comparison to other tanks at the site which range from approximately 50,000 – 4,000,000 gallons. The product that will be handled in Tank 3 during the emissions test is Performance Grade (PG) 64-22 asphalt (which is the standard asphalt base product), which comprises approximately 60% of the market products sold by Hudson. Venting from this tank is through a single goose-neck fitting located at the top of the tank. Tank 3, and all of Hudson's bulk tanks are welded tanks (not riveted). Other than the atmospheric vents, there are no other vents, pressure vents, or other such emission points from the tanks located at Hudson's terminal. One exception is on three of the newest tanks constructed at the terminal, which were designed with explosion panels. These panels are sealed under normal operating conditions, but will break away in the event a dangerous condition develops where pressures become elevated.

The EPA Testing Order specifies the use of Method 204, Criteria for and Verification of a Permanent or Temporary Total Enclosure ("TTE"). The TTE method is a "temporarily installed enclosure that completely surrounds a source of emissions such that all VOC emissions that are not directed through [a] control device (i.e., uncaptured) are captured by the enclosure and contained for discharge through ducts that allow for the accurate measurement of the uncaptured VOC emissions (EPA, Air Emission Measurement Center). Hudson does not believe that the TTE method is appropriate for measuring emissions from a bulk liquid asphalt tank and, further, expects that parameters such as minimum flow rates specified by the test method could not be met without inducing an artificial source of flow. Given that the source is a welded tank equipped with a single atmospheric vent and no other emission source, Hudson believes that the TTE method is unnecessary and would introduce an inherent bias to the test.

As a result of the discussion above, Hudson, in collaboration with Triton and its stack testing contractor, have identified a more standard method to complete the Tank 3 testing in lieu of the TTE method. As presented in the attached test protocol, the proposed method will eliminate the artificial draft concerns and produce a more accurate result. Hudson proposes to complete testing over a 3-day period rather than the 15 day period noted by the EPA, as it is believed that there should not be more variability over the longer period. Lastly, during the 3-day test, tank filling will occur to monitor for working losses in addition to typical standing losses. However, tank filling may not be completed from a ship or barge if a comparable fill rate can be achieved by other methods.

Closing

Upon EPA's review of this response, Hudson would be happy to meet to discuss the data submitted and testing methodology proposed. Please note that Hudson is determined to only perform the subject testing using methodology appropriate for the source and one that does not artificially introduce biases. As it is, the alternative testing method proposed by Hudson is extremely costly and disruptive to facility operations. It is obviously important that the test be accurate, representative of actual operating conditions, and only be completed a single time given the complexities involved. Thank you for your attention to this matter. If you should have any questions or comments, or would like to meet please contact us at 203.458.7200.

Sincerely,

Paul C. Simonetta, CHMM
Senior Project Manager

Christopher E. Marchesi
President

enclosure

cc: Mr. Dennis Leamy, Hudson Terminal

Ref. No. 104841L01

Table 1
Total Asphalt Shipped - 2011 Through 2016
Hudson Terminal
Providence, Rhode Island

Year	Total Asphalt Shipped
2011	34,955,398
2012	30,848,680
2013	22,539,833
2014	38,416,191
2015	30,668,634
2016	28,422,970

Table 2
Asphalt Received - 2011
Hudson Terminal
Providence, Rhode Island

Date	Asphalt Product	Quanity (Gallons)
Feb-11	PG 64-28	7,107
Mar-11	PG 64-22	21,033
Mar-11	PG 64-28	7,070
Mar-11	RS1	4,901
03/21/11	PG 64-22	5,021,705
Apr-11	PG 58-28	167,540
Apr-11	RS1	5,795
May-11	PG 58-28	100,388
May-11	RS1	18,407
May-11	RS1H	5,922
06/01/11	PG 64-22	4,225,323
June-11	PG 64-22	123,486
Jun-11	PG 58-28	397,933
Jun-11	RS1	26,373
Jun-11	RS1H	6,290
06/26/11	PG 64-28	4,432,816
Jul-11	PG 58-28	397,733
Jul-11	PG 64-28C	79,630
Jul-11	RS1	11,268
Jul-11	RS1H	6,628
07/19/11	PG 64-22	3,302,933
07/19/11	PG 64-22	526,895
07/19/11	PG 64-28	988,647
Aug-11	PG 64-28	14,263
Aug-11	PG 52-34	182,147
Aug-11	PG 58-28	42,647
Aug-11	PG 64-28	112,807
Aug-11	PG 64-28	30,870
Aug-11	RS1	14,536
Sep-11	PG 52-34	288,360
Sep-11	PG 64-28	118,072
Sep-11	RS1	23,486
Sep-11	RS1H	9,673
09/15/11	PG 64-22	3,323,095
09/22/11	PG 64-22	1,357,551
Oct-11	SS1	1,957
Oct-11	RS1	35,688
10/09/11	PG 64-22	1,338,384
11-Oct	PG 52-34	346,693
10/27/11	PG 64-22	1,344,653
Nov-11	SS1	789
Nov-11	RS1	54,043
11/04/11	PG 64-22	2,007,100
Dec-11	PG 58-28	71,744
Dec-11	RS1	2,665
12/31/11	PG 64-22	1,319,549
Total Product Received		**31,926,593**

Table 3
Asphalt Received - 2012
Hudson Terminal
Providence, Rhode Island

Date	Asphalt Product	Quanity (Gallons)
Jan-12	RS1	4,880
Mar-12	PG 64-28	49,347
Mar-12	SS1	815
Mar-12	RS1	11,218
03/18/12	PG 64-22	2,149,360
Apr-12	PG 64-28	144,707
Apr-12	SS1	1,758
Apr-12	RS1	7,222
04/06/12	PG 64-22	1,419,614
04/12/12	PG 64-22	1,977,244
May-12	RS1	21,690
05/09/12	PG 64-22	1,317,130
05/22/12	PG 64-28	2,928,228
Jun-12	PG 64-28C	7,126
Jun-12	PG 76-28	397,005
Jun-12	RS1	35,186
06/12/12	PG 64-22	1,671,623
Jul-12	PG 64-28	5,179
Jul-12	PG 64-28E	20,765
Jul-12	PG 64-28E	5,184
Jul-12	PG 76-28	471,035
Jul-12	RS1	33,005
07/31/12	PG 64-22	2,551,519
Aug-12	PG 64-28E	79,481
Aug-12	PG 76-28	309,272
Aug-12	RS1	14,292
08/13/12	PG 64-22	1,152,400
08/13/12	PG 64-28	1,154,370
Sep-12	PG 64-22	212,565
Sep-12	PG 64-28E	77,940
Sep-12	PG 76-28	112,788
Sep-12	SS1	5,583
Sep-12	RS1	26,511
09/23/12	PG 64-22	1,199,386
Oct-12	PG 76-28	47,091
Oct-12	RS1	24,817
10/12/12	PG 64-28	2,976,951
Nov-12	PG 64-22	5,414
Nov-12	PG 64-28	297,416
Nov-12	RS1	23,352
11/16/12	PG 64-22	1,446,784
Dec-12	PG 64-28	449,440
Dec-12	PG 58-28	120,256
Dec-12	RS1	19,442
Total Product Received		**24,986,390**

Table 6
Asphalt Received - 2015
Hudson Terminal
Providence, Rhode Island

Date	Asphalt Product	Quanity (Gallons)
1/2/15	PG 64-22	6,815,006
1/12/15	PG 64-22	2,941,450
5/6/15	PG 64-28	1,590,359
6/20/15	PG 64-22	2,308,617
6/23/15	PG 64-22	3,698,519
7/25/15	PG 64-22	1,863,510
8/15/15	PG 70-22	4,341,424
10/25/15	PG 64-22	1,582,443
11/5/15	PG 64-22	2,359,905
Total Product Received		**27,501,232**

Table 7
Asphalt Received - 2016
Hudson Terminal
Providence, Rhode Island

Date	Asphalt Product	Quanity (Gallons)
1/13/16	PG 64-22	1,362,624
2/26/16	PG 64-22	2,393,398
3/3/16	PG 64-28	2,613,857
3/23/16	PG 70-22	3,167,833
3/31/16	PG 64-28	2,603,910
4/26/16	PG 64-28	766,653
5/19/16	PG 64-22	2,343,876
6/6/16	PG 64-22	5,682,794
6/20/16	PG 64-22	352,294
7/13/16	PG 64-22	4,092,634
8/9/16	PG 64-22	2,552,138
8/15/16	PG 64-22	1,371,807
8/30/16	PG 64-22	2,348,088
9/19/16	PG 64-22	2,327,089
10/21/16	PG 64-22	2,748,656
12/6/16	PG 64-22	1,162,514
12/23/16	PG 64-22	7,174,965
Total Product Received		**45,065,129**

Table 9
General Tank Information
Hudson Terminal
Providence, Rhode Island

Tanks	Tank Height	Tank Diameter	Year Built/ Operational	Construction Vertical	Roof Type Fixed	Average Storage Temp F	Roof Insulation	Shell Insulation	Shell Capacity Gallons	Safe Fill Capacity Gallons	Heat loss Millions BTU/hr
1	48'- 01/4"	60' - 0"	1962	Steel	Cone	280	3" 8# min wool	4" fiberglass	1,015,114	937,363	0.347
2	48' - 01/4"	60' - 0"	1962	Steel	Cone	360	3" 8# min wool	4" fiberglass	1,014,770	936,994	0.509
3	48' - 01/4"	60' - 0"	1962	Steel	Cone	280	3" 8# min wool	4" fiberglass	1,016,036	936,505	0.347
4	48' - 0"	80' - 4"	1962	Steel	Cone	280	3" 8# min wool	4" fiberglass	1,816,812	1,737,628	0.5
6	32' - 0"	25' - 0"	1962	Steel	Cone	340	3" 8# min wool	3" asbestos block	117,692	104,479	0.154
7	39' - 11"	30' - 0"	1962	Steel	Cone	340	3" 8# min wool	2"foam /2" fiberglass	211,260	197,092	0.184
8	39' - 11"	30' - 0"	1962	Steel	Cone	340	3" 8# min wool	4" fiberglass	211,343	197,176	0.184
9	40' - 10"	30' - 5"	1973	Steel	Cone	340	3" 8# min wool	4" fiberglass	220,510	206,075	0.19
13	40' - 01/2"	15' - 0"	1977	Steel	Cone	360	Mastic	4" fiberglass	52,725	46,781	0.095
14	40' - 01/2"	15' - 0"	1977	Steel	Cone	360	Mastic	4" fiberglass	52,750	46,803	0.095
17A	24' - 0"	15' - 0"	1962	Steel	Cone	125	3" 8# min wool	1 1/2 foam / 1 1/2 fiber	31,702	25,637	0.017
18	15' - 0"	10' - 0"	1998	Steel	Flat	125	3" insulation	3" insulation	6,300	6,000	0.008
19	60' 0"	80' 0"	2007	Steel	Cone	280	3" 8# min wool	1 1/2 foam / 1 1/2 fiber	2,269,811	2,178,545	0.702
20	48' - 0"	120' - 0"	1971	Steel	Cone	280	3" 8# min wool	1 1/2 foam / 1 1/2 fiber	4,050,121	3,929,913	1.046
21	60' 0"	80' 0"	2007	Steel	Cone	280	3" 8# min wool	1 1/2 foam / 1 1/2 fiber	2,271,619	2,180,353	0.702
22	60' 0"	80' 0"	2007	Steel	Cone	280	3" 8# min wool	1 1/2 foam / 1 1/2 fiber	2,268,929	2,174,516	0.702
25	64' - 0"	100' - 0"	1984	Steel	Cone	280	3" 8# min wool	1 1/2 foam / 1 1/2 fiber	3,753,150	3,640,372	0.96

TEST PROTOCOL

Liquid Asphalt Tank Headspace and Loading Operations Emission Measurement Test Program

Prepared for: **HUDSON TERMINAL CORP.**
29 Terminal Road
Providence, RI 02905

Contact Name: c/o Triton Environmental, Inc.
Christopher Marchesi
Contact No. (203) 458-7200

Prepared by: **AIR TOX ENVIRONMENTAL COMPANY, INC.**
479 Tolland Turnpike
Willington, Connecticut 06279

Contact Name: Dominik Grzywacz, QSTI
Project Engineer
Contact No. (860) 487-5606 ext. 116

Air Tox Project No. 17011

April 2017

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List of Tables and Figures

Appendix

1.0 INTRODUCTION

Air Tox Environmental Company, Inc. (Air Tox) of Willington, Connecticut has been retained by Triton Environmental, Inc. as a representative of Hudson Terminal Corporation to perform volatile organic compound (VOC) and hazardous air pollutant (HAP) emission rate measurements from the headspace of the liquid asphalt tank (Tank #3), as well as, VOC emission rate measurements from the truck loading operations located at 29 Terminal Road, Providence, Rhode Island. The purpose of this test program will be to satisfy the United States Environmental Protection Agency's (USEPA) testing order for information under Section 114 of the Clean Air Act. This testing order was received by Hudson Terminal Corp on January 13, 2017.

The tank headspace VOC emission rate quantification will be conducted under two (2) measurement scenarios of standing loss (static) and working loss (adding product). Additionally, VOC emission rate measurements from ten (10) trucks will be performed during the loading operations at the distribution rack. The sampling and analyses will be carried out in conformance with the regulations of the USEPA and the Rhode Island Department of Environmental Management (RI DEM) during this test program.

The compliance demonstration test program described herein will be performed during the second or third week in September 2017. The month of September has been chosen since it represents the annual average ambient weather conditions such as atmospheric temperature and pressure. The program will be performed under the supervision of Mr. Dominik Grzywacz, Project Engineer of Air Tox. Mr. Grzywacz will supervise all field operations during the performance of this test program. Mr. Dennis Leamy of Hudson Terminal Corp. will oversee process operations during this test program. Listed below are the personnel and responsibilities to ensure the successful completion of this test program

TABLE 1-1
LIST OF KEY PERSONNEL

Name/Title	Representing	Responsibility	Phone No.	Email Address
Dominik Grzywacz Project Engineer	Air Tox	Site Project Manager	(860) 748-6179	dominik@airtoxenviro.com
Eric Dithrich Vice President	Air Tox	Project Oversight	(860) 833-2099	eric@airtoxenviro.com
Christopher Marchesi	Triton Env.	Project Oversight	(203) 458-7200	cmarchesi@tritonenvironmental.com

Section 2.0 of this test protocol presents the scope of the sampling program. A description of the process and operations is presented in Section 3.0. Sampling and analytical methodologies are presented in Section 4.0. The Air Tox Quality Assurance Plan is detailed in Section 5.0.

2.0 SCOPE OF THE SAMPLING PROGRAM

This section details the scope of the proposed emissions testing program, including the sampling parameters, proposed test methodologies, sampling locations, and operating conditions. All sampling and analyses will be carried out in accordance with the regulations of the governing federal and state agencies. Testing will be based on the methodologies outlined in the 40CFR60 Appendix A, reference methods. Detailed summaries of the proposed test methodologies to be used are presented below.

2.1 Sampling Parameters

Emission measurements will be performed at the liquid asphalt tank's exhaust vent for all of the parameters listed below in Table 2-1, in accordance with the respective test methodologies.

TABLE 2-1
SAMPLING PARAMETERS & METHODS

EMISSION PARAMETER	REFERENCE METHOD
• Traverse Point Locations	• Method 1/1A
• Volumetric Flow Rate	• modified Method 2/2C
• Total Hydrocarbons (THC) as propane (C_3H_8)	• Method 25A
• Methane (CH_4) Content	• Method 320
• Hazardous Air Pollutant (HAP) Content	• EPA TO-15

2.2 Storage Tank Multiple Day VOC & HAP Sampling

Since the VOC concentration inside the tank will not change during the static state sampling, it is our assessment that evaluating the static pressure changes over a three (3) day period will be proportionately representative of average annual emissions (as well as hourly and daily emissions). Consequently, Air Tox proposes to perform the tank static state headspace sampling over three (3) twenty-four (24) hour continuous periods of time , rather than the fifteen (15) days outlined in the Testing Order. In addition to the static state sampling, Air Tox will evaluate the emission rates of the tank vent during a single (1) tank filling event, as outlined in the Section 114 Testing Order.

The Section 114 Testing Order outlined the utilization of EPA Reference Method 204 during this test program. However, the use of Method 204 in this situation induces an "artificial" draft on the tank headspace in order to achieve emission rate measurements. The artificially induced draft caused by using Method 204 will effectively create an above average biased emission characterization without correction.

Due to the inherent potential bias associated with the use of this approach, Air Tox proposes to utilize a more conventional strategy to achieve representative emissions. Specifically, Air Tox will integrate the use of low flow rate (2 – 20 scfm) measurement technology (i.e. vane anemometer and bidirectional high accuracy low pressure transducers -0.5 to 0.5 inch W.C. Omega PX656-01DI or equivalent) into an automated measurement system in order to achieve an accurate flow rate measurement. Additionally, during the tank loading scenario, the exhaust vent volumetric flow rate will be determined by the calculated volume change in the tank.

The VOC emission concentration from the tank exhaust vent will be continuously measured by utilizing EPA Reference Method 25A and reported in the units of part per million wet basis (ppmw), as total hydrocarbons (THC), as propane (C_3H_8). The methane (CH_4) content will also be measured in accordance with EPA Reference Method 320 simultaneous with the THC emission measurements. The measured CH_4 emission concentration in the units of ppmw will be subtracted from the THC emission concentration to determine the non-methane hydrocarbon (NMHC) concentration of the gas stream.

The HAP emission concentration measurements will be collected in accordance with EPA Toxic Organic Method TO-15. A summa canister similar to the one present below in Figure 2-1 will be used to collect the HAP sample. A total of two (2) samples will be collected during this test program. A single (1) sample will be collected while the tank is in a static state and a single (1) sample will be collect while the tank is at a working state (during the single filling operation).

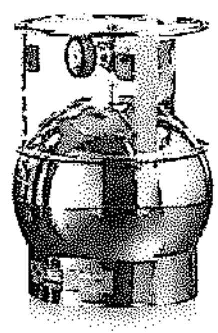


Figure 2-1 TO-15 Summa Canister

2.3 Truck Loading VOC & HAP Sampling

The VOC emission concentration from truck loading will be measured from the tanker truck hatch during loading operations of ten (10) tanker trucks. VOC emissions will be measured in accordance with EPA Reference Method 25A and reported in the units of part per million wet basis (ppmw), as total hydrocarbons (THC), as propane (C_3H_8). The methane (CH_4) content will also be measured in accordance with EPA Reference Method 320 simultaneous with the THC emission measurements. The measured CH_4 emission concentration in the units of ppmw will be subtracted from the THC emission concentration to determine the non-methane hydrocarbon (NMHC) concentration of the gas stream. The flow rate of the exhaust gas stream will be determined from the tanker fill rate.

2.4 Tank Headspace Sampling Location

Tank No. 3 is currently configured with a single exhaust vent as presented in figure 2-2. The gas stream vents downward in a cane style 8 inch piece of black pipe. In order to cause the least amount of permanent modification to the existing vent system, a new 8 inch vent spool piece will be fabricated by Hudson Terminal and installed where the cane style exhaust screen is bolted to the pipe . The new spool piece will include enough (≈ 3 - 4) sampling ports to accommodate this test program. The ports will be located in accordance with EPA Method 2 criteria, a minimum of 8 duct diameters downstream from the nearest flow disturbance and a minimum of 2 duct diameters upstream.

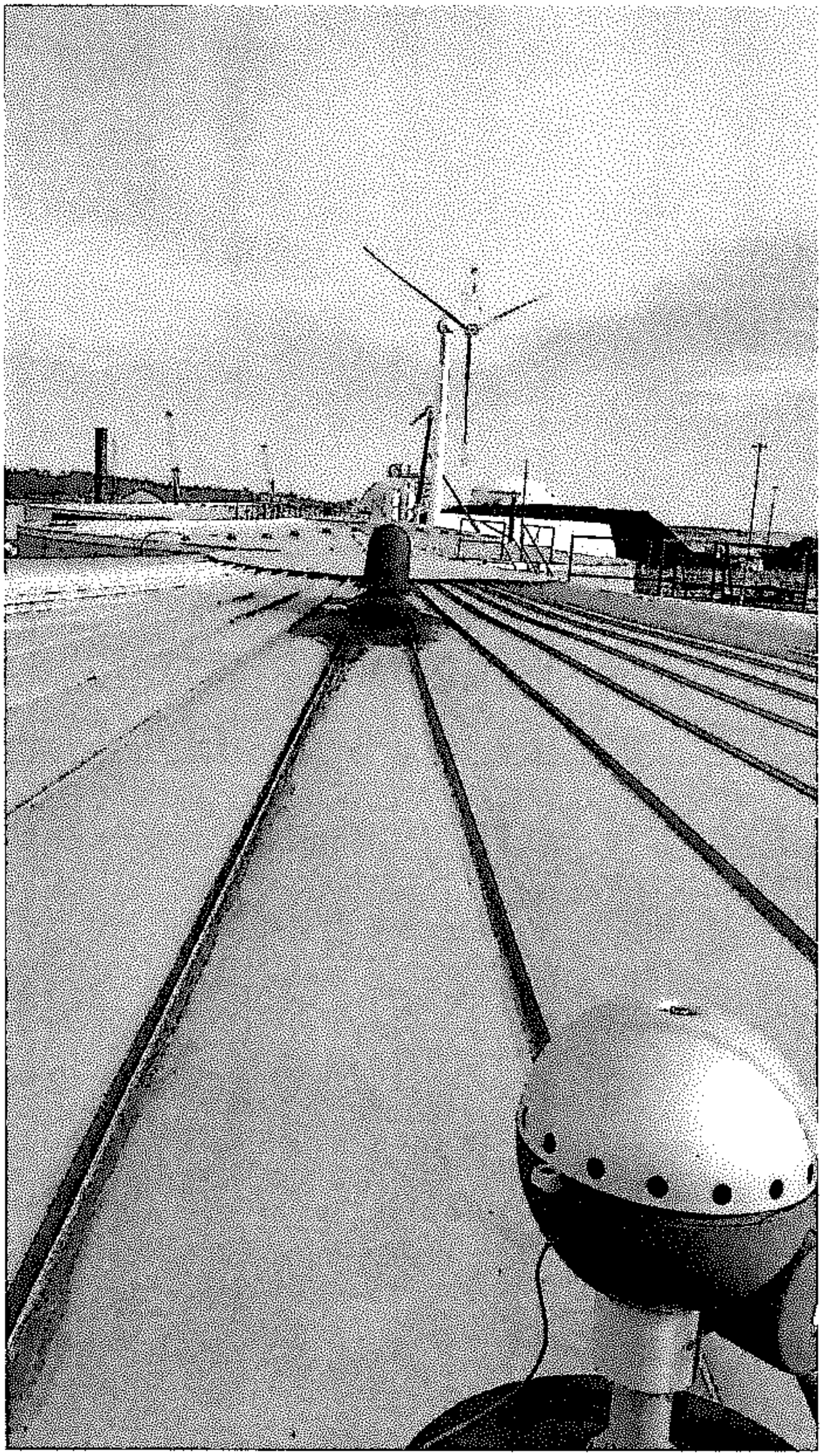
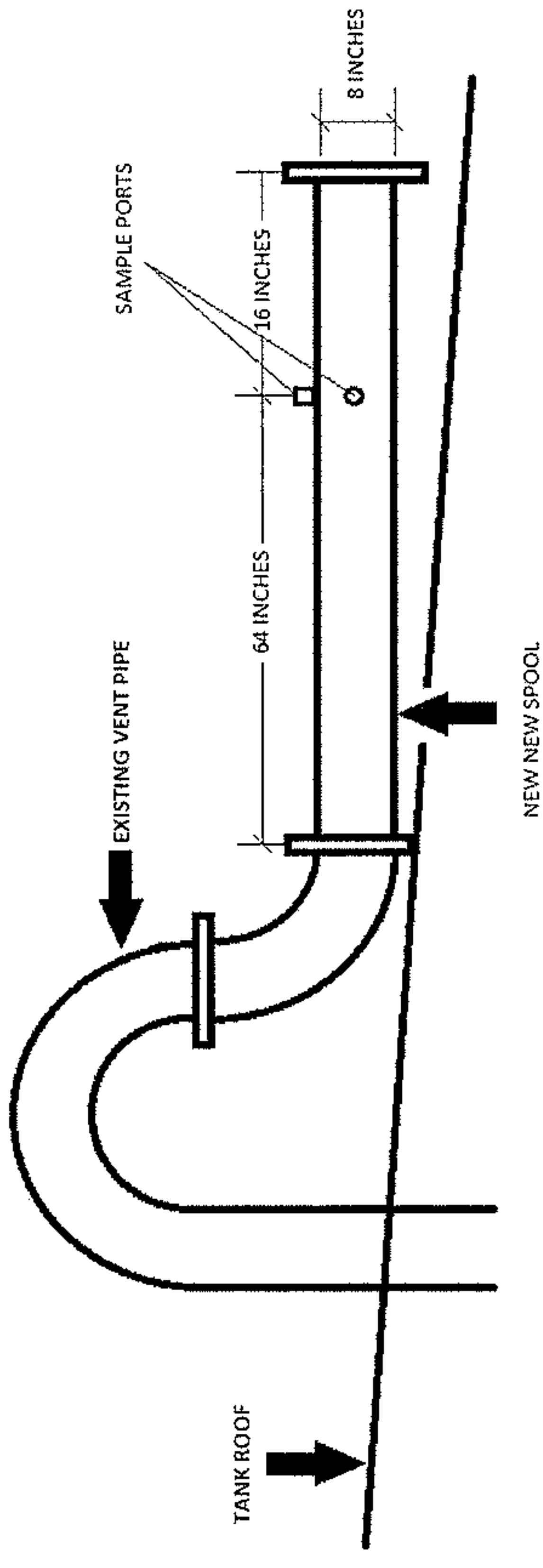


Figure 2-2 Tank Vent Configuration

FIGURE 2-3 PROPOSED SAMPLE PORT LOCATION



3.0 PROCESS & OPERATIONS

The facility description has been included in the cover letter of this submittal. A photograph of tank No. 3 is presented below in Figure 2-3.

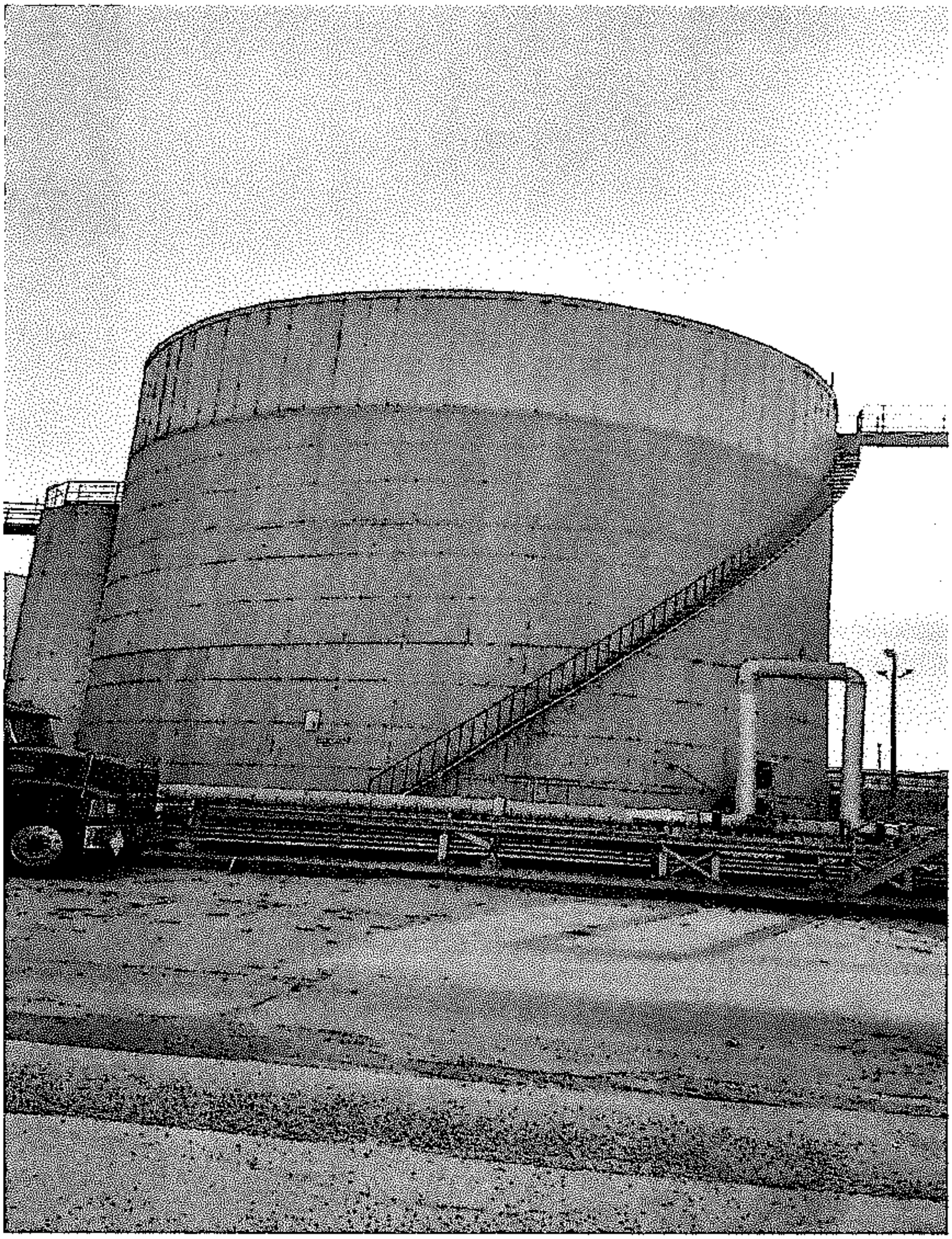


Figure 2-3 Tank No. 3

4.0 SAMPLING & ANALYTICAL METHODOLOGY

Emission measurements will be performed during this test program to determine concentrations emissions rates of volatile organic compounds (VOC) and HAPs. Presented below are the sampling and analytical methodologies which will be used to measure these constituents of the various exhaust streams associated with this program. All emissions measurements will be conducted at the sampling ports located at the outlet vent of the tank, except for the tanker truck loading portion of the testing. The locations will be fabricated in the new vent spool piece based on the criteria detailed in US EPA Reference Method 1.

4.1 Instrument Reference Method Sampling System

Continuous VOC emission monitoring will be performed at the outlet vent of the tank in order to determine emission concentrations of VOCs as total hydrocarbons (THC) according to EPA Reference Method 25A. A schematic of the instrumental reference method (IRM) sampling system is presented in Figure 4-1. Stack gas will be drawn through a stainless steel probe, heated Teflon sample line (300°F nominal) by a leakless Teflon diaphragm pump. THC samples will be fed directly from the heated sample line to the THC analyzer.

4.1.1 Total Hydrocarbon Analyzers

The VOC concentration of the exhaust gas will be monitored utilizing a California Analytical Instruments (CAI) Model 600HFID heated total hydrocarbon analyzer. The CAI 600HFID is a microprocessor-based flame ionization detector (FID), which will respond to organic compounds in methane equivalent. Calibrations will be performed using certified propane cylinders. The Model 600HFID will be operated on a tentatively 0 to 5,000 ppm range, as propane and subject to change.

4.1.2 Methane Determination by FTIR

The methane content of the gas stream will be measured using EPA Reference Method 320. The MKS2030 FTIR instrument will consist of a medium-high resolution interferometer, heated fixed path absorption cell, a detector, electronics package, and a computer. The gas transport path inside the FTIR will be heated to 150 °C (302 °F) while the absorption cell was maintained at 150 °C (302 °F). Certified gas cylinder mixtures (accurate to ±2%) of the analyte at concentration near the emission source levels (if possible/applicable). A modified version of analyte spiking will be used to verify the effectiveness of the sampling system for the target analyte. Analyte spiking will be performed at the beginning and the end of the entire test program by introducing the spike gas at a point prior the filter. The spiking will be completed following the acquisition of the pre- and post-test CTS spectra. High purity nitrogen or zero air will be used for purging sample lines, sampling system components, for diluting sample (if necessary) and calibration gases, and for system leak checks. MKS software will be used to control the sampling system, acquire spectra and post process the spectra to provide quantification of the analyte in the sample. All sample periods will be identified with a unique file name. At the beginning and end of the test program a calibration transfer standard (CTS) gas will passed through the FTIR gas cell. The results will be analyzed to verify that they are within 5% of the certified value. Reference spectra will be obtained for each analyte and interferant, CTS, and tracer gas. Spectra will be obtained from the EPA spectral library on the Emission Measurement Technical Information Center (EMTIC) or may be prepared by a qualified individual. The initial sample spectra will be evaluated to determine if the sample matrix is consistent with the pre-test assumptions and if the instrument configuration is suitable.

4.1.3 Analyzer Calibrations

A two (2) point (zero and span) calibration will be performed directly on the analyzer (bypassing the sample transport system) at the beginning of the test program to demonstrate analyzer linearity and calculate a predicted response for the low-level and mid-level gases. Calibration error is then determined by introducing the low-level and mid-level gases to the sampling system and comparing the actual response values with the predicted response calculations.

A zero and mid-level bias check and calibration drift check will also be performed daily. An injection point at the sample extraction probe will be used for the introduction of gases to the entire sample transport and conditioning system for daily calibration checks. EPA Protocol 1 gases (if available), at concentrations within the ranges specified in each test method, will be used for all calibrations. Calibration drift, if any, will be used to correct the average test run concentrations. Procedures and calculations contained in EPA Reference Method 25A, Sections 6, 7, & 8 will be used to determine the average corrected stack concentration of the measured constituents for each test run.

4.1.4 Data Acquisition

All gaseous emissions data will be recorded using an ESC 8816 data logger supported by ESC's software on a laptop PC. The signals from the analyzers are "viewed" by the data logger at 1-second intervals, from which 1-minute averages are formed. The ESC software will then be used to generate reports for discrete test periods. The corrected test averages will then be used to calculate emission rates, in accordance with Reference Method 25A.

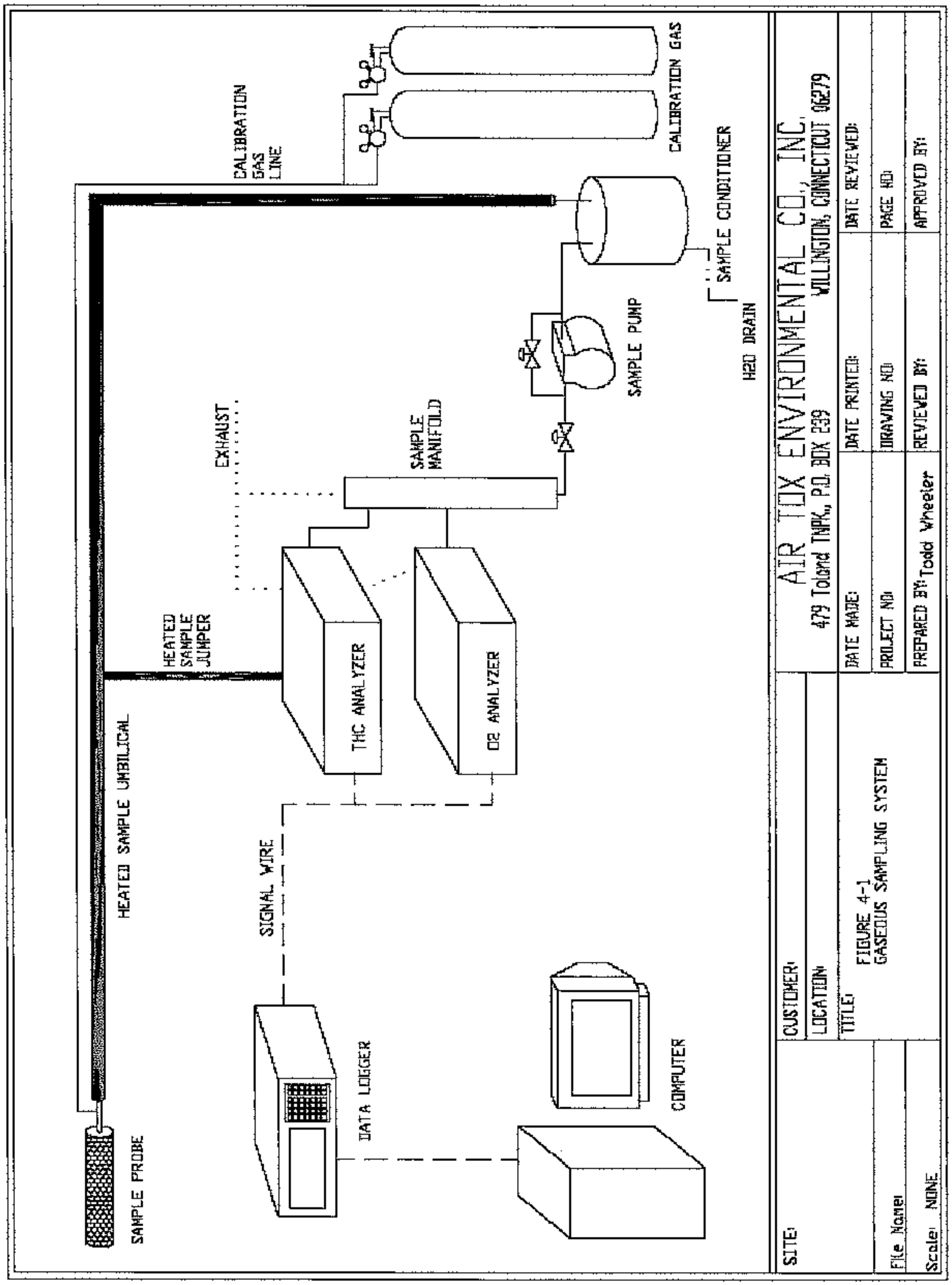


Figure 4-1 Instrument Reference Method Sampling Diagram

4.2 Volumetric Flow Rate Measurements

Exhaust stack volumetric flow rate will be determined in accordance with EPA Reference Methods 1 and 2. Velocity measurements will be recorded at each of three traverse points simultaneously (single port). Air Tox will use a series of three stainless S-type pitots or a single standard type pitot and thermocouple. The single or series of pitot tubes will be connected to dedicated Ashcroft Model CXLdp (or equivalent) differential pressure transducers (-0.5 to 0.5 in. W.C.). The series of thermocouples will be connected to multiple dedicated Omega temperature transmitters. The differential pressure and temperature outputs (4-20mA) will be continuously recorded using an ESC 8816 data logger supported by ESC's software on a PC. The signals from the analyzers will be "viewed" by the data logger at 1-second intervals, from which one-minute averages will be formed. The ESC software will then be used to generate reports for discrete test periods. Printouts of these periods will be contained in the Appendix of the test report.

A schematic of the flow rate reference method sampling configuration is presented in Figure 4-2.

Data collected in accordance with Reference Methods 2 will be used to calculate the outlet vent volumetric flow rates in actual, standard cubic feet per minute. Average volumetric flow rates will then be used to calculate mass emission rates of the VOCs and HAPs.

4.3 HAP Sampling using EPA Method TO-15

Hazardous air pollutants (HAPS) will be determined by collecting a sample in a prepared, pre- evacuated Summa canister with a calibrated flow orifice meter to allow canister filling for approximately 30 minutes. The sample will then be delivered to the canister via a short length of ¼" OD Teflon tubing and a short ¼" stainless steel probe which will be positioned in the exhaust vent center using a leak-free Swagelok fitting. A total of two Summa canister samples will be collected during this program. A single (1) will be collected during the multiple day static tank operating condition and one (1) one during the tank loading condition.

Maxxam Analytics of Burlington, Ontario will prepare the canister prior to being used and will conduct the final analysis of the Summa canisters in accordance with EPA Method TO-15. Analysis of HAPs will be determined by Gas Chromatography/Mass Spectrometry (GC/MS) and will consist of the standard compound associated with TO-15.

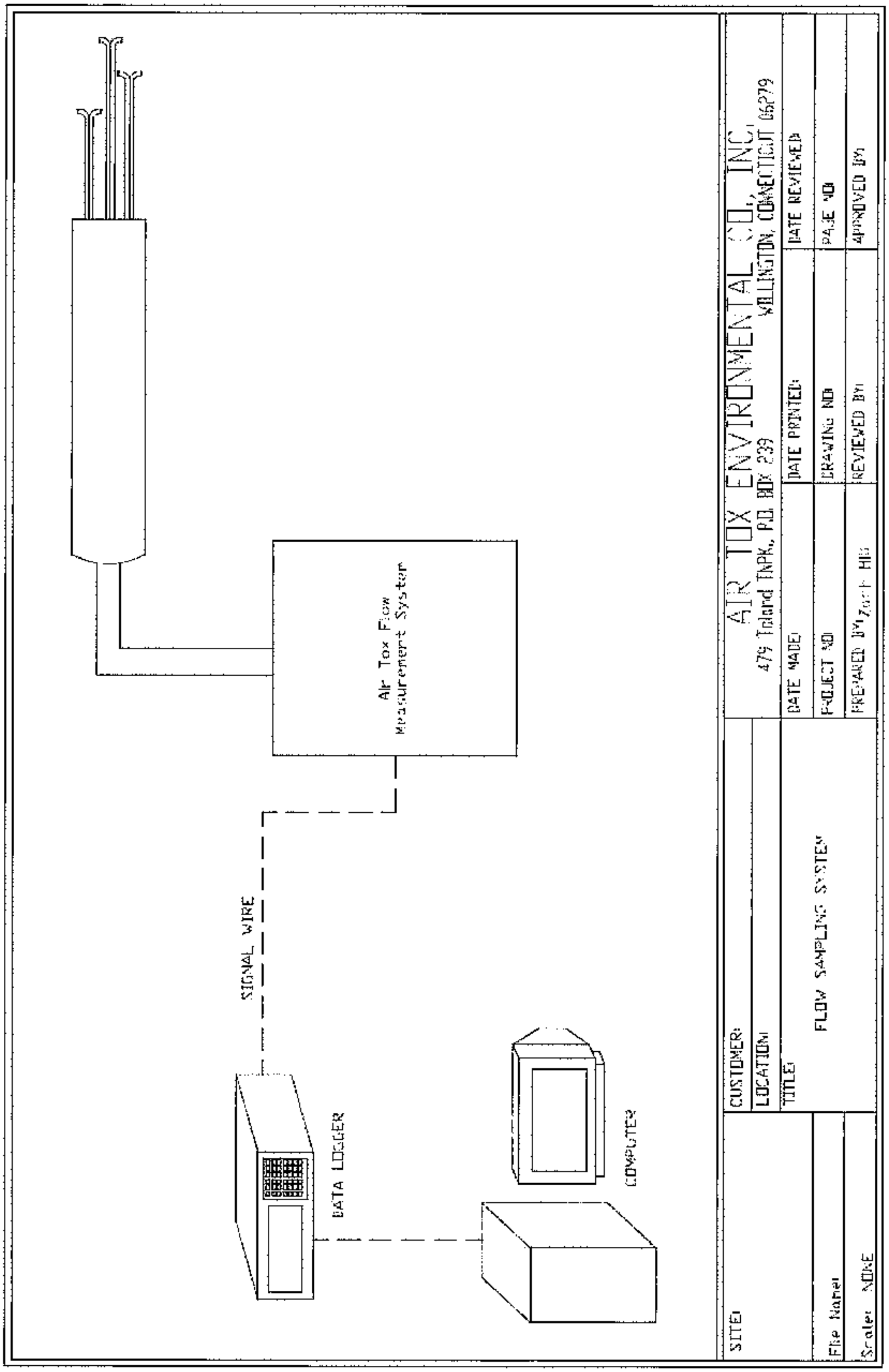


Figure 4-2 Flow Rate Sampling Schematic

5.0 QUALITY ASSURANCE

The project manager is responsible for implementation of the quality assurance program as applied to this project. Implementation of quality assurance procedures for source measurement programs is designed so work is done:

- By competent, trained individuals experienced in the methodologies being used.
- Using properly calibrated equipment.
- Using approved procedures for sample handling and documentation.

Measurement devices, pitot tubes, dry gas meters, thermocouples and portable gas analyzers are uniquely identified and calibrated with documented procedures and acceptance criteria before and after each field effort. Records of all calibration data are maintained in the files.

Data are recorded on standard forms. Bound field notebooks are used to record observations and miscellaneous elements effecting data, calculations, or evaluation.

Prior to the test program Air Tox provides the following:

- Calibrations of all pitot tubes, dry gas meters, orifice meters, sampling nozzles, and thermocouples that are used during the test. All calibrations are performed within six months prior to the test date.

Calibration gases utilized for gaseous analysis methods will be prepared in accordance with EPA Protocol 1, and will be certified to be within ±2% of the cylinder "tag" value concentration. Analyzer linearity, bias, calibration drift, and calibration drift corrections will be determined in accordance with Reference Method 7E.

Specific details of the Air Tox QA program for stationary air pollution sources may be found in "Quality Assurance Handbook for Air Pollution Measurement Systems", Volume III (EPA-600/4-7-027b).

APPENDIX

STACK TEST CALCULATIONS

EMISSION CALCULATION SYMBOLS

A_s = cross-sectional area of stack, ft^2

C = actual particulate concentration, grains/acf

C_p = pitot tube coefficient, dimensionless

C_{ppm}= stack concentration, ppm

C_{std} = particulate concentration, standard conditions, grains/dscf

$Catch_{mg}$ = total particulate collected, milligrams

D_n = nozzle diameter, inches

D_s = average stack gas density, lbs/ft^3

EA = excess air, %

F = Fuel factor, F-factor, dscf/MMBtu

GCV = gross calorific value of fuel, Btu/lb

I = isokinesis

L_a = allowable leak rate, cfm

L_f = final leak rate, cfm

M_d = molecular weight of stack gas, lbs/lb-mole (dry)

M_s = molecular weight of stack gas, lbs/lb-mole (wet)

M_w = molecular weight of specific compound, lbs/lb-mol

P_{abs} = absolute stack gas pressure, inches Hg

P_{bar} = barometric pressure, inches Hg

P_s = stack static pressure, inches H_2O

P_{std} = standard pressure, 29.92 inches Hg

Q_{acfm} = stack volumetric flow rate actual, acfm

Q_{dscfm} = stack volumetric flow rate corrected to standard conditions, dry, dscfm

Q_{scfm} = stack volumetric flow rate corrected to standard conditions, scfm

$R_{lbs/dscf}$ = pollutant emission rate, lbs/dscf

$R_{lbs/hr}$ = pollutant emission rate, lbs/hr

$R_{lbs/MMBtu}$ = particulate emission rate, lbs/MMBtu

T = total sampling time, minutes

T_{abs} = absolute stack gas temperature, °R

T_m = dry gas meter temperature, °F

T_s = stack temperature, °F

T_{std} = standard temperature, 68°F (equivalent to 528°R)

V_l = volume of liquid collected in impingers, ml

V_m = total meter sample volume, acf

V_{mc} = total meter volume corrected for excessive leakage, acf

$V_m std$= total meter volume corrected to standard conditions, dscf

V_s = stack velocity, fpm

V_{sg} = volume of liquid collected in silica gel, grams

Y = dry gas meter calibration factor, dimensionless

ΔH_{avg} = average orifice pressure drop, inches H_2O

ΔP_{avg} = average velocity head

9. Excess Air (***EA***) Units = percent (%)

$$EA = \left(\frac{\%O_2 - 0.5(\%CO)}{(0.264 * \%N_2) - (\%O_2 - 0.5(\%CO))} \right) * 100$$

10. Average Stack Velocity (V_s) Units = fpm

$$V_s = 5129.4 * C_p * \sqrt{\Delta P_{avg}} * \sqrt{\frac{T_s avg + 460}{\left(P_{bar} + {P_s avg}/{13.6} \right) * M_s}}$$

11. Stack Volumetric Flow Rate, Actual (Q_{acfm}) Units = acfm

$$Q_{acfm} = V_s * A_s$$

12. Stack Volumetric Flowrate, Corrected (Q_{scfm}) Units = scfm

$$Q_{scfm} = Q_{acfm} * \left(\frac{T_{std} + 460}{T_s avg + 460} \right) * \left(\frac{P_{bar} + {P_s avg}/{13.6}}{P_{std}} \right)$$

13. Stack Volumetric Flowrate, Corrected, Dry (Q_{dscfm}) Units = dscfm

$$Q_{dscfm} = Q_{acfm} * \left(1 - \frac{\%H_2O}{100} \right) * \left(\frac{T_{std} + 460}{T_s avg + 460} \right) * \left(\frac{P_{bar} + {P_s avg}/{13.6}}{P_{std}} \right)$$

14. Isokinesis (I) Units = percent (%)

$$I = \frac{5.67 * (T_s avg + 460) * V_m std}{\left(P_{bar} + {P_s avg}/{13.6} \right) * V_s * T * \left(1 - \frac{\%H_2O}{100} \right) * \left(D_n^2 * {0.7854}/{144} \right)}$$

15. Module Sampling Rate (ΔH) Units = inches H_20

$$\Delta H = \Delta P * \left[846.72 * D_n * \Delta H_{@} * C_p * (1 - \%H_2O \right]^2 * \frac{M_d}{M_s} * \frac{T_m}{T_s} * \frac{P_s}{P_{bar}}$$

16. Destruction Efficiency (**%*DE***) Units = percent %

$$\%DE = \frac{Lbs/hr_{inlet} - Lbs/hr_{outlet}}{Lbs/hr_{inlet}} * 100$$

23. Particulate Concentration (**C_{std}@ 12% CO_2**) Units = gr/dscf

$$C_{std} @ 12\% \, CO_2 = \frac{12}{\%CO_2} * C_{std}$$

24. Particulate Emission Rate (**$R_{lbs/hr}$**) Units = lbs/hr

$$R_{lbs/hr} = 0.008571 * C_{std} * Q_{dscfm}$$

25. Fuel-Factor, F-Factor (**F**) Units = dscf/MMBtu

$$F = \frac{10^6 * (3.64\%H + 1.53\%C + 0.57\%S + 0.14\%\%N - 0.46\%O)}{GCV}$$

26. Particulate Emission Rate (**$R_{lbs/MMBtu}$**) Units = lbs/MMBtu

$$R_{lbs/MMBtu} = 0.0001429 * C_{std} * F * \left[\frac{20.9}{20.9 - \%O_2}\right]$$

27. Particulate Concentration @ 50% Excess Air (**C_{std}@ 50% EA**) Units = gr/dscf

$$C_{std} @ 50\% \, EA = \frac{\%EA + 100}{150} * C_{std}$$

28. Particulate Concentration Based on Stack Gas Weight (lbs/1000 lbs stack gas,uncorrected)

$$C_{lb} = 0.1429 * \frac{C}{D_s}$$

29. Particulate Concentration Based on Stack Gas Weight @12% CO_2

$$C_{lb} @ 12\% \, CO_2 = \frac{C_{std} @12\%CO_2 * 0.104 * 528}{(0.44\%CO_2) + (0.28\%CO) + (0.28\%N_2) + (0.32\%O_2)}$$

30. Particulate Concentration Based on Stack Gas Weight @50% EA

$$C_{lb} @ 50\% \, EA = \frac{C_{std} @50\%EA * 0.104 * 528}{(0.44\%CO_2) + (0.28\%CO) + (0.28\%N_2) + (0.32\%O_2)}$$

EMISSION CALCULATION SYMBOLS

$\%C$ =	percent by weight of carbon in fuel
$\%H$ =	percent by weight of hydrogen in fuel
$\%O$ =	percent by weight of oxygen in fuel
$\%S$ =	percent by weight of sulfur in fuel

$\%CO$ =	percent carbon monoxide by volume (dry basis)
$\%N$ =	percent by weight of nitrogen in fuel
$\%CO_2$ =	percent carbon dioxide by volume (dry basis)
$\%N_2$ =	percent nitrogen by volume (dry basis)
$\%O_2$ =	percent oxygen by volume (dry basis)

UNIT ABBREVIATIONS

acf	= actual cubic feet
acfm	= actual cubic feet per minute
cfm	= cubic feet per minute
dscf	= dry standard cubic feet
dscfm	= dry standard cubic feet per minute
dscf/MMBtu	= dry standard cubic feet per million British Thermal Unit
°F	= degrees Fahrenheit
fpm	= feet per minute
g	= grams
gr	= grains
gr/acf	= grains per actual cubic foot
gr/dscf	= grains per dry standard cubic foot
in. H_20	= inches water
in. Hg	= inches Mercury
lbs/dscf	= pounds per dry standard cubic foot
lbs/MMBtu	= pounds per million British Thermal Unit
lbs/ft^3	= pounds per cubic foot
lbs/hr	= pounds per hour
mg	= milligrams
ml	= milliliter
ppm	= parts per million
°R	= degrees Rankine
scfm	= standard cubic feet per minute

EMISSION CALCULATION SYMBOLS

A_s = cross-sectional area of stack, ft^2
C = actual particulate concentration, grains/acf
C_p = pitot tube coefficient, dimensionless
C_{ppm}= stack concentration, ppm
C_{std} = particulate concentration, standard conditions, grains/dscf
$Catch_{mg}$ = total particulate collected, milligrams
D_n = nozzle diameter, inches
D_s = average stack gas density, lbs/ft^3
EA = excess air, %
F = Fuel factor, F-factor, dscf/MMBtu
GCV = gross calorific value of fuel, Btu/lb
I = isokinesis
L_a = allowable leak rate, cfm
L_f = final leak rate, cfm
M_d = molecular weight of stack gas, lbs/lb-mole (dry)
M_s = molecular weight of stack gas, lbs/lb-mole (wet)
M_w = molecular weight of specific compound, lbs/lb-mol
P_{abs} = absolute stack gas pressure, inches Hg
P_{bar} = barometric pressure, inches Hg
P_s = stack static pressure, inches H_2O
P_{std} = standard pressure, 29.92 inches Hg
Q_{acfm} = stack volumetric flow rate actual, acfm
Q_{dscfm} = stack volumetric flow rate corrected to standard conditions, dry, dscfm
Q_{scfm} = stack volumetric flow rate corrected to standard conditions, scfm
$R_{lbs/dscf}$ = pollutant emission rate, lbs/dscf
$R_{lbs/hr}$ = pollutant emission rate, lbs/hr
$R_{lbs/MMBtu}$ = particulate emission rate, lbs/MMBtu
T = total sampling time, minutes
T_{abs} = absolute stack gas temperature, °R
T_m = dry gas meter temperature, °F
T_s = stack temperature, °F
T_{std} = standard temperature, 68°F (equivalent to 528°R)
V_l = volume of liquid collected in impingers, ml
V_m = total meter sample volume, acf
V_{mc} = total meter volume corrected for excessive leakage, acf
$V_m std$= total meter volume corrected to standard conditions, dscf
V_s = stack velocity, fpm
V_{sg} = volume of liquid collected in silica gel, grams
Y = dry gas meter calibration factor, dimensionless
ΔH_{avg} = average orifice pressure drop, inches H_2O
ΔP_{avg} = average velocity head

1. Absolute Stack Gas Temperature (T_{abs}) Units = degrees Rankine

$$T_{abs} = T_s + 460$$

2. Absolute Stack Gas Pressure (P_{abs}) Units = inches Hg

$$P_{abs} = P_{bar} + P_s / 13.6$$

3. Allowable Leak Rate (L_a) Units = cfm

$$L_a = 0.02 \text{ cfm} \quad \underline{\text{or}} \quad 0.04 * \left(\frac{V_m}{T}\right)$$ (whichever is less)

4. Meter Volume, Corrected for Excessive Leak Rate (V_{mc}) Units = acf

if $L_f > L_a$ use V_{mc} in place of V_m in all subsequent equations

$$V_{mc} = V_m - [T * (L_f - L_a)]$$

5. Meter Volume Corrected to Standard Conditions ($V_m std$) Units = dscf

$$V_m std = V_m * Y * \left(\frac{T_{std} + 460}{T_m avg + 460}\right) * \left(\frac{P_{bar} + \Delta H_{avg}/13.6}{P_{std}}\right)$$

6. Moisture Content of Stack Gas (% H_2O) Units = % by volume

$$\% H_2O = \frac{0.04707(V_l + V_{sg})}{V_m std + 0.04707 * (V_l + V_{sg})} * 100$$

7. Molecular Weight of Stack Gas (M_s) Units = lbs/lb-mole

$$M_s = \left[(0.44 * \%CO_2) + (0.28 * \%CO) + (0.28 * \%N_2) + (0.32 * \%O_2)\right] * \left(1 - \frac{\%H_2O}{100}\right) + (0.18 * \%H_2O)$$

8. Average Stack Gas Density (D_s) Units = lbs/ft^3

$$D_s = 0.0458 * M_s * \left(\frac{P_{bar} + P_s avg/13.6}{T_s avg + 460}\right)$$

9. Excess Air (*EA*) Units = percent (%)

$$EA = \left(\frac{\%O_2 - 0.5(\%CO)}{(0.264 * \%N_2) - (\%O_2 - 0.5(\%CO))}\right) * 100$$

10. Average Stack Velocity (V_s) Units = fpm

$$V_s = 5129.4 * C_p * \sqrt{\Delta P_{avg}} * \sqrt{\frac{T_s avg + 460}{\left(P_{bar} + {}^{P_s avg}/_{13.6}\right) * M_s}}$$

11. Stack Volumetric Flow Rate, Actual (Q_{acfm}) Units = acfm

$$Q_{acfm} = V_s * A_s$$

12. Stack Volumetric Flowrate, Corrected (Q_{scfm}) Units = scfm

$$Q_{scfm} = Q_{acfm} * \left(\frac{T_{std} + 460}{T_s avg + 460}\right) * \left(\frac{P_{bar} + {}^{P_s avg}/_{13.6}}{P_{std}}\right)$$

13. Stack Volumetric Flowrate, Corrected, Dry (Q_{dscfm}) Units = dscfm

$$Q_{dscfm} = Q_{acfm} * \left(1 - \frac{\%H_2O}{100}\right) * \left(\frac{T_{std} + 460}{T_s avg + 460}\right) * \left(\frac{P_{bar} + {}^{P_s avg}/_{13.6}}{P_{std}}\right)$$

14. Isokinesis (*I*) Units = percent (%)

$$I = \frac{5.67 * (T_s avg + 460) * V_m std}{\left(P_{bar} + {}^{P_s avg}/_{13.6}\right) * V_s * T * \left(1 - \frac{\%H_2O}{100}\right) * \left(D_n^2 * {}^{0.7854}/_{144}\right)}$$

15. Module Sampling Rate (ΔH) Units = inches H_20

$$\Delta H = \Delta P * \left[846.72 * D_n * \Delta H_{@} * C_p * (1 - \%H_2O\right]^2 * \frac{M_d}{M_s} * \frac{T_m}{T_s} * \frac{P_s}{P_{bar}}$$

16. Destruction Efficiency (*%DE*) Units = percent %

$$\%DE = \frac{Lbs/hr_{inlet} - Lbs/hr_{outlet}}{Lbs/hr_{inlet}} * 100$$

17. Capture Efficiency (%*CE*) Units = percent %

$$\%CE = \frac{MeasuredVOC@Inlet}{VOCApplied} * 100$$

18. Stack Concentration (C_{ppm}) Units = ppm

$$C_{ppm} = \frac{Catch_{mg}}{Volume_{cubicmeters}} * \frac{24.06}{M_w}$$

$$C_{ppm} = \frac{R_{lbs/dscf} * (385.1 * 10^6)}{M_w}$$

19. Pollutant Emission Rate ($R_{lbs/hr}$ *and* $R_{lbs/dscf}$) Units = lbs/hr and lbs/dscf

$$R_{lbs/hr} = C_{ppm} * Q_{scfm} * M_w * (15.58 * 10^{-8})$$

$$R_{lbs/hr} = R_{lbs/dscf} * Q_{dscfm} * 60$$

$$R_{lbs/dscf} = \frac{C_{ppm} * M_w}{385.1 * 10^6}$$

20. Particulate Concentration, Actual Conditions (*C*) Units = gr/acf

$$C = \frac{0.01543 * Catch_{mg} * 528 * \left(P_{bar} + {P_s avg}/{13.6}\right)}{V_m std * (T_s avg + 460) * 29.92}$$

21. Particulate Concentration, Standard Conditions (C_{std}) Units = gr/dscf

$$C_{std} = 0.01543 * \frac{Catch_{mg}}{V_m std}$$

22. Particulate Concentration, corrected to 7% oxygen ($C_{7\%}$) Units = gr/dscf @ 7% O_2

$$C_{7\%} = C_{std} * \frac{(20.9 - 7)}{(20.9 - \%O_2)}$$

23. Particulate Concentration (C_{std}@ 12% CO_2) Units = gr/dscf

$$C_{std} @ 12\% \; CO_2 = \frac{12}{\%CO_2} * C_{std}$$

24. Particulate Emission Rate ($R_{lbs/hr}$) Units = lbs/hr

$$R_{lbs/hr} = 0.008571 * C_{std} * Q_{dscfm}$$

25. Fuel-Factor, F-Factor (F) Units = dscf/MMBtu

$$F = \frac{10^6 * (3.64\%H + 1.53\%C + 0.57\%S + 0.14\%\%N - 0.46\%O)}{GCV}$$

26. Particulate Emission Rate ($R_{lbs/MMBtu}$) Units = lbs/MMBtu

$$R_{lbs/MMBtu} = 0.0001429 * C_{std} * F * \left[\frac{20.9}{20.9 - \%O_2}\right]$$

27. Particulate Concentration @ 50% Excess Air (C_{std}@ 50% EA) Units = gr/dscf

$$C_{std} @ 50\% \; EA = \frac{\%EA + 100}{150} * C_{std}$$

28. Particulate Concentration Based on Stack Gas Weight (lbs/1000 lbs stack gas,uncorrected)

$$C_{lb} = 0.1429 * \frac{C}{D_s}$$

29. Particulate Concentration Based on Stack Gas Weight @12% CO_2

$$C_{lb} @ 12\% \; CO_2 = \frac{C_{std} @12\%CO_2 * 0.104 * 528}{(0.44\%CO_2) + (0.28\%CO) + (0.28\%N_2) + (0.32\%O_2)}$$

30. Particulate Concentration Based on Stack Gas Weight @50% EA

$$C_{lb} @ 50\% \; EA = \frac{C_{std} @50\%EA * 0.104 * 528}{(0.44\%CO_2) + (0.28\%CO) + (0.28\%N_2) + (0.32\%O_2)}$$

31. Standard Deviation

$$s_d = \left[\frac{\sum_{i=1}^{n} d_i^2 - \frac{\left(\sum_{i=1}^{n} d_i\right)^2}{n}}{n - 1}\right]^{\frac{1}{2}} \quad \text{(or)} \quad s_d = \sqrt{\frac{\Sigma X^2 - n\overline{X}^2}{n-1}}$$

32. Confidence Coefficient

$$CC = t_{0.975} \frac{S_d}{\sqrt{n}}$$

33. t-values

n	$t_{0.975}$
9	2.306
10	2.262
11	2.228
12	2.201

34. Relative Accuracy

$$RA = \frac{\overline{d} + |CC|}{\overline{RM}}$$

where: $\overline{d}$ = absolute mean of differences (RM - CEM)

$|CC|$ = Confidence Coefficient

$\overline{RM}$ = absolute mean of RM values

35. Least Squares (y = mx + b)

slope

$$m = \frac{(n\Sigma xy) - (\Sigma x \Sigma y)}{n\Sigma x^2 - (\Sigma x)^2}$$

intercept

$$b = \frac{1}{n}(\Sigma y - m\Sigma x)$$

EMISSION CALCULATION SYMBOLS

$\%C$ =	percent by weight of carbon in fuel
$\%H$ =	percent by weight of hydrogen in fuel
$\%O$ =	percent by weight of oxygen in fuel
$\%S$ =	percent by weight of sulfur in fuel

$\%CO$ =	percent carbon monoxide by volume (dry basis)
$\%N$ =	percent by weight of nitrogen in fuel
$\%CO_2$ =	percent carbon dioxide by volume (dry basis)
$\%N_2$ =	percent nitrogen by volume (dry basis)
$\%O_2$ =	percent oxygen by volume (dry basis)

UNIT ABBREVIATIONS

acf	= actual cubic feet
acfm	= actual cubic feet per minute
cfm	= cubic feet per minute
dscf	= dry standard cubic feet
dscfm	= dry standard cubic feet per minute
dscf/MMBtu	= dry standard cubic feet per million British Thermal Unit
°F	= degrees Fahrenheit
fpm	= feet per minute
g	= grams
gr	= grains
gr/acf	= grains per actual cubic foot
gr/dscf	= grains per dry standard cubic foot
in. H_20	= inches water
in. Hg	= inches Mercury
lbs/dscf	= pounds per dry standard cubic foot
lbs/MMBtu	= pounds per million British Thermal Unit
lbs/ft^3	= pounds per cubic foot
lbs/hr	= pounds per hour
mg	= milligrams
ml	= milliliter
ppm	= parts per million
°R	= degrees Rankine
scfm	= standard cubic feet per minute

Conversion Factors

To Convert	To Obtain	Multiply By
atmospheres	pounds/in^2	1.470×10^1
	inches Hg	2.992×10^1
	mm Hg	7.600×10^2
bars	atmospheres	9.869×10^1
	pounds/in^2	1.450×10^1
	mm Hg	7.497×10^2
inches Hg	atmospheres	3.342×10^2
	pounds/in^2	4.912×10^{-1}
	inches H_2O	1.360×10^1
inches H_20	atmospheres	2.458×10^{-3}
	inches Hg	7.355×10^{-2}
	pounds/in^2	3.613×10^{-2}
mm Hg	atmospheres	1.316×10^{-3}
	inches Hg	2.540×10^1
pounds/in^2	atmospheres	6.804×10^{-2}
	inches Hg	2.036
	kPascals	6.895
	inches H_2O	2.771×10^1
cubic inches	ft^3	5.787×10^{-4}
	m^3	1.639×10^{-5}
cubic meters	ft^3	3.531×10^1
	in^3	6.1023×10^4
cubic feet	m^3	2.832×10^{-2}
gallons	liters	3.785
grams	pounds	2.205×10^{-3}
pounds	grains	7.000×10^3
	kilograms	4.536×10^{-1}
quarts	liters	9.463×10^{-1}
ounces	liters	2.957×10^{-2}

Ideal Gas Law: **PV = nRT** where: P = atmospheres (pressure)
V = liters (volume)
n = moles (number of moles)
R = 0.082057 (molar constant)
T = Kelvins (temperature)

Avogadro's # = 6.022×10^{23} molecules = 1 mol = 22.41 L @ 1 atm & 273 K